A Modular Capability for Community Modeling of Flares/CMEs and their Interplanetary Impacts

Heliophysics Science Division

GSFC / UMichigan

Overview and Status

Team:

- Spiro Antiochos, PI, *GSFC/UMich*
- Tamas Gombosi, Co-I/Inst. PI, *UMich*
- Rick DeVore, Co-I, *GSFC*
- Bart van der Holst, Co-I, *UMich*
- Judy Karpen, Co-I, *GSFC*
- Chip Manchester, Co-I, *Umich*
- Pete Schuck, Co-I GSFC
- Igor Sokolov, Co-I, *UMich*
- Gabor Toth, Co-I, *Umich*
- **Numerous PostDocs and students**

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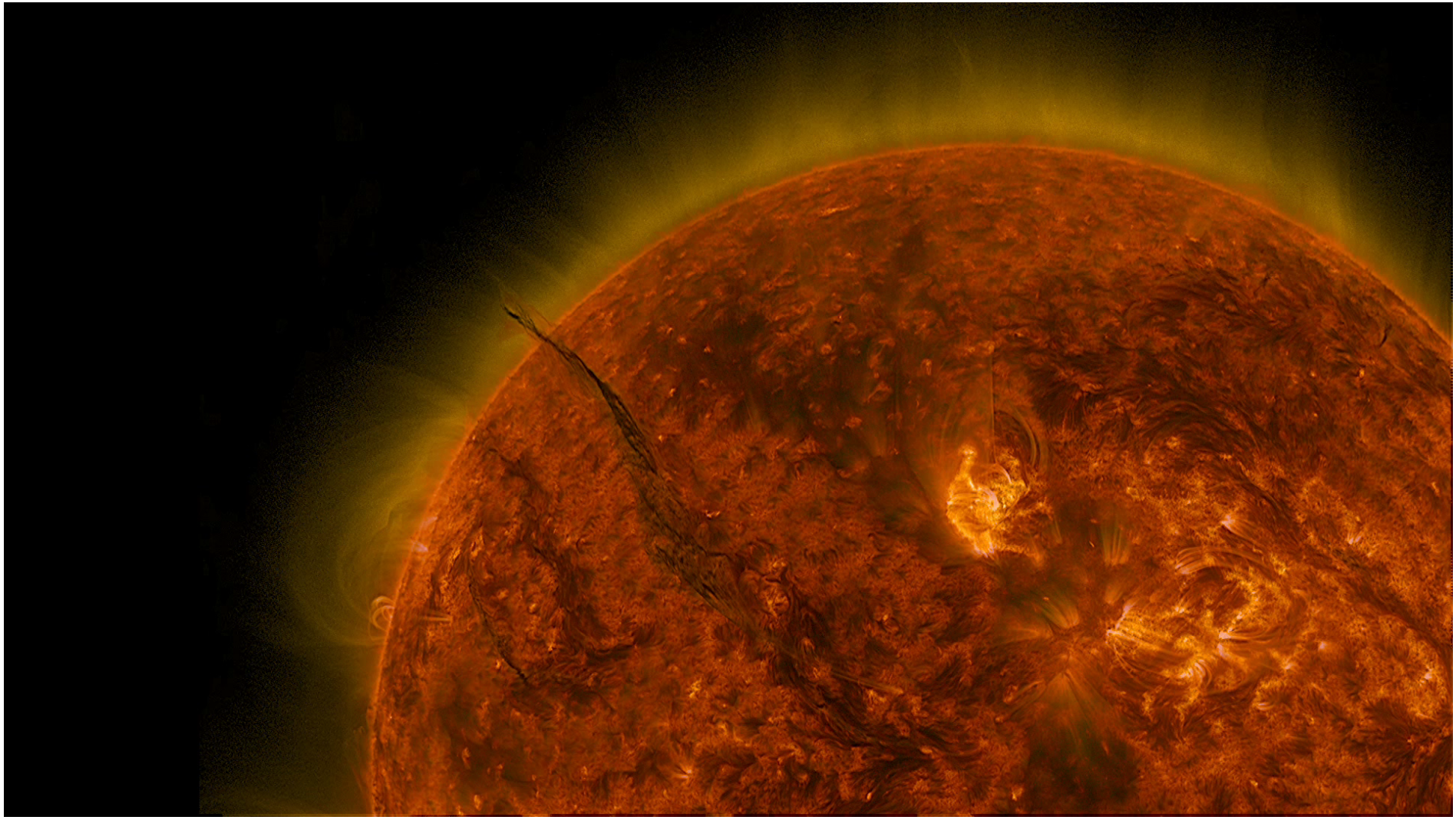
Modular Solar Eruptions Capability (MSEC)

Science Objective: Eruptive flares & CMEs (SEEs) and their interplanetary impacts

Methodology: Enable *community* exploratory science



MSEC Modeling Successes

- *AWSoM:* quasi-steady 3D background from chromosphere to 5 AU
  - Includes comprehensive physics of corona and wind **at CCMC**
- *AWSoM-R*: 3D background model with breakthrough soltn. to TR problem
  - Runs faster than real time,
  - Ideal candidate for transition to operations, **at CCMC**
- *EEGGL*: eruptive event generator model
  - First community model for exploratory studies
  - True game changer, **at CCMC**

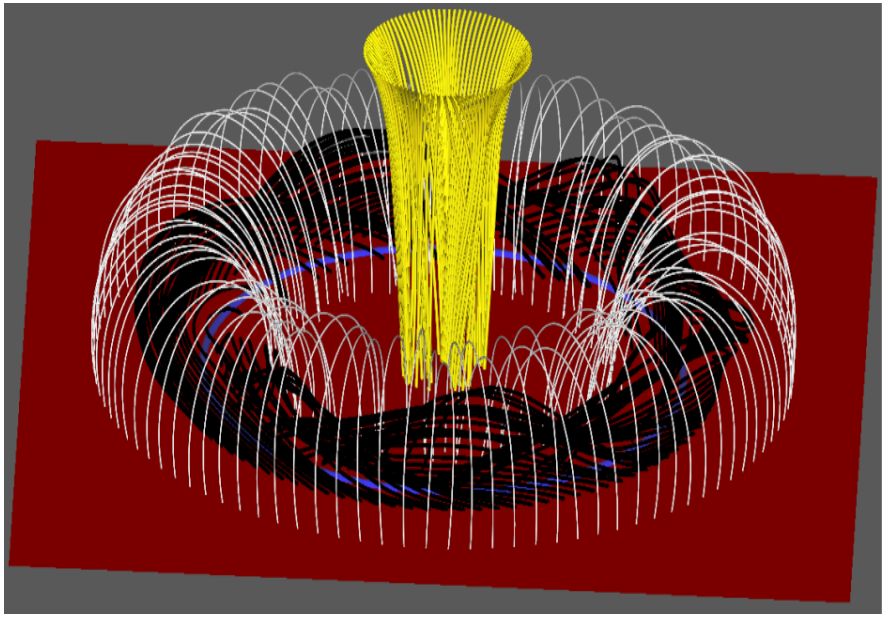
- All models at CCMC have extensive analysis tools for direct validation with mission data
  - COADRED breakthrough soltn. to SDO/HMI artifacts
- 250p training manual for suite of models with library of examples
  - all interfaces being developed with CCMC (e.g., *EEGGL*) incorporating user feedback

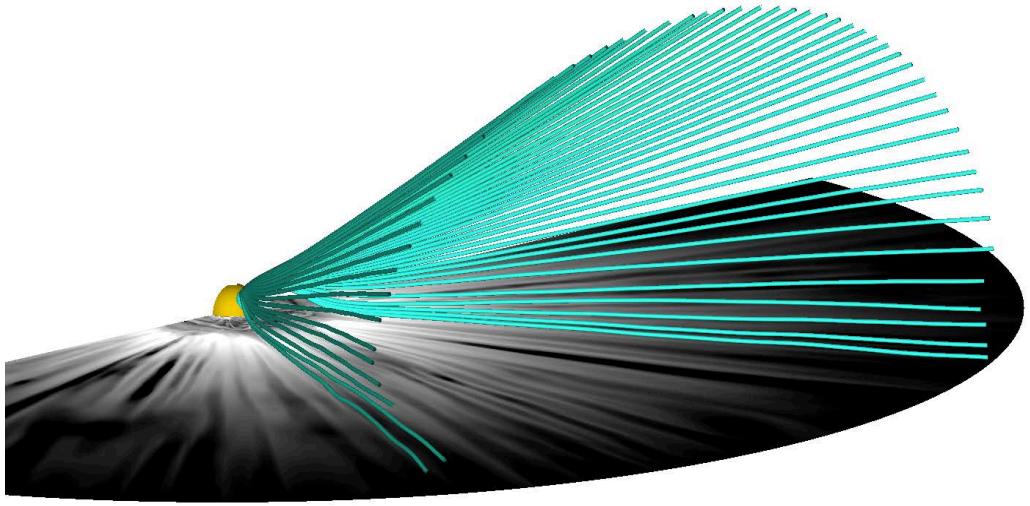
MSEC Modeling Successes

- *SWARM:* Active region scale flux emergence model
  - Includes full convection dynamics
  - Under development for delivery to CCMC
- *MHD-EPIC:* *breakthrough software technology* for embedding PIC physics into global extended MHD model
  - Validated and being used for science runs
  - See following talk for application to magnetosphere
- *MFLAMPA:* SEP shock acceleration and transport
  - Couples MHD and diffusion equation
  - Under development for delivery to CCMC
- *AMPS:* particle tracker suite
  - Extensive capabilities**, at CCMC**

MSEC Science Successes

- First demonstration of SEE free energy buildup by helicity condensation
  - (Antiochos, Zhao et al, Knizhnik et al)
- First demonstration of dynamic slow wind with large angular extent in heliosphere
  - (Higginson et al)
- First demonstration of jet driven by breakout
  - Key implications for all eruptions
  - (Karpen et al, Szente et al, Wyper et al)





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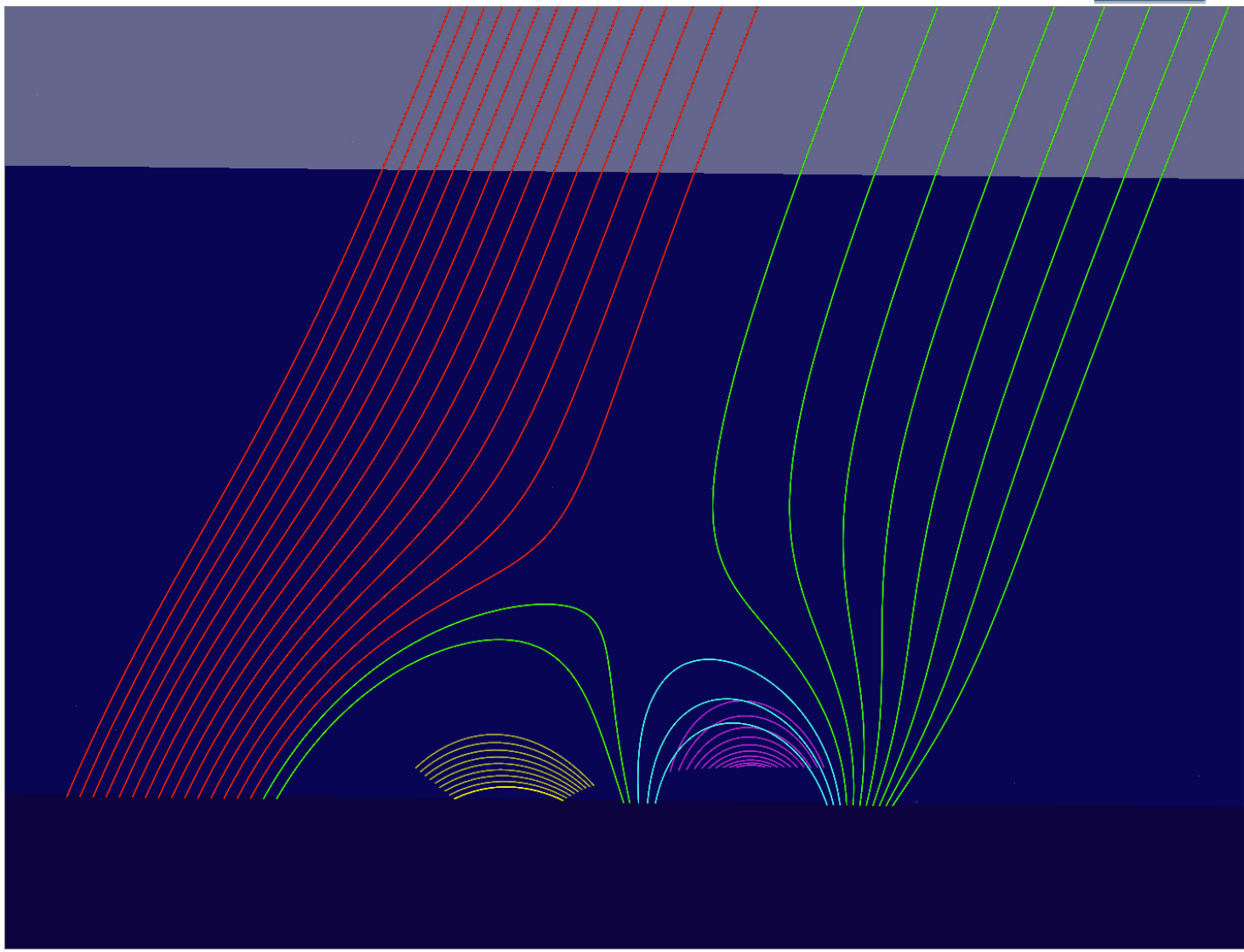
MSEC Science Successes

- Eruption cannot be due to ideal instability
- Due to breakout reconnection (Wyper et al Nature 2017)



MSEC Educational Successes

Six PhDs trained:

- Zhenguang Huang. A New Feature of the Quiet Sun Corona During Solar Minimum. (2014)
- Rona Oran. Coronal Heating and Solar Wind Acceleration by Alfvén Wave Turbulence: a Global Computational Model and Observations. (2014).
- Meng Jin. Numerical Study of Coronal Mass Ejections, Shocks, and Turbulence: from Chromosphere to 1 AU. (2014).
- Kalman Knizhnik. The Role of Magnetic Helicity in the Structure and Heating of the Sun's Corona (2016)
- Aleida Higginson. The Dynamics of the S-Web and Implications for the Solar Wind and Heliosphere (2017)
- Dmitry Borovikov. Towards a Forecasting Capability in Solar Energetic Particle Modeling (2017)

Future Directions

Modeling:

- Extend *EEGL* to variety of onset mechanisms
- Incorporate emergence *SWARM* into *AWSoM/EEGL*
- Incorporate kinetics from *MHD-EPIC* into *AWSoM/EEGL*
- Transition to operational capability

Science:

- Self-consistent eruption from emergence or helicity condensation or …
- Incorporate kinetic resistivity into eruption/activity models